When in doubt:
The role of constraints in scientific research

Phuong (Phoebe) Dinh
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Tufts University
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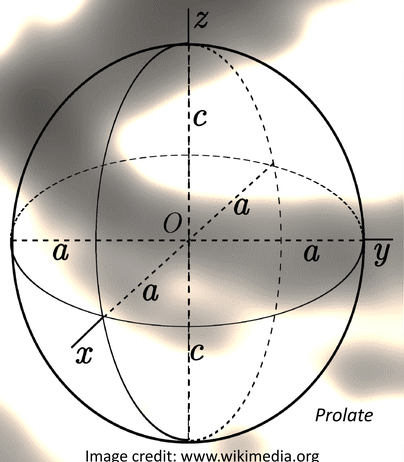
Introduction

In the sciences, constraints are often invoked to nudge our research questions in directions that are hopefully right and eliminate explanations that are (just as hopefully) wrong. The lack of observations and founding principles of young sciences make constraints particularly important. Yet imposing constraints without consideration for accumulating empirical data could restrict one's perspectives and prevent one from developing the right theory. This project studies a parallel between two instances in the history of science where constraints were challenged. The first lesson of the parallel draws from Newton's disputes with Leibniz and Huygens regarding the legitimacy of gravity as the cause of observed celestial motions – a longstanding stalemate stretching from the late 1680s up until Newton's passing in 1727. The second lesson concerns the famous mental imagery debate between Stephen Kosslyn and Zenon Pylyshyn, in which the validity of depictive representations of information was contested since the early 1970s up until today. Insights from the two cases could elucidate the *practical importance of constraints* and the conditions that license a *departure from them*.



Prolate

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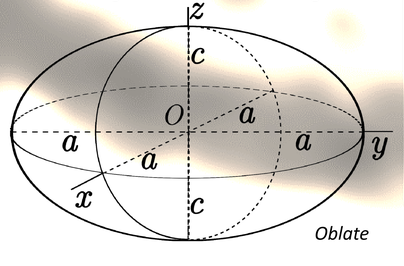
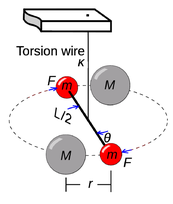


Oblate

Central parallels

	Newton	*Kosslyn*
Constraint	Action is caused by **contact** between objects. Contact was the only mechanism known to mechanistically explain action in objects (Huygens, Leibniz).	Any feasible cognitive theory must be **implementable on a computer**. A computer instantiation of any theory allow the components of that theory to be studied and explained mechanistically (Pylyshyn).
Central claim	Gravity toward a body is composed of attraction toward the individual particles of that body.	Visual images are depictive data structures that retain the spatial and visual properties of information.
Constraint violation	It was unclear how exactly gravity could affect celestial bodies without a contact mechanism – space is otherwise devoid of substance.	The underlying data structure of all computers then were symbolic and thus descriptive in nature. Computers thus could not instantiate this theory.
Evidence for central claim	Cavendish's experiment (1798) meant to study the density gradient toward the center of the Earth, but inadvertently also measured the gravitational constant (G). It was the first **experimental** piece of evidence for the law of universal gravity. Maupertuis organized an expedition to Lapland to measure the length of a degree of arc of the meridian. His results favored the conclusion that the Earth was oblate (flattened at the poles) rather than prolate (lengthened along the polar diameter) – a **prediction** explicitly made by Newton's theory of universal gravity.	Experiments using reaction time (RT) **repeatedly** demonstrated a **linear** relationship between the distance scanned on a mental image and the time taken to scan. Other spatial and visual properties of mental images (e.g. proportion, size) were also shown through RT data. Brain imaging techniques (e.g. Positron Emission Tomography, functional Magnetic Resonance Imaging) demonstrated that many of the **brain areas activated during visual tasks are also activated during mental visual imagery tasks**. Computer models were used to empirically test specific hypotheses.



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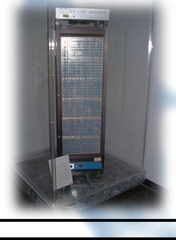

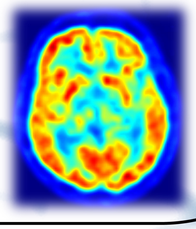

Image credit: http://philosophyofbrains.com/wp-content/uploads/2015/07/PSM_V26_D768_Brain_of_gauss-1.jpg

Tentative conclusion

The evidences stated above were not without flaws. In Newton's case, the exact value of G is still questionable– the experiments used today to determine G are but variations of Cavendish's original experiment, with no other means to crosscheck the results. Similarly, proponents of mental imagery still have to show that brain imaging data demonstra the functional involvement of visual brain areas in imagery. In both cases, Newton and Kosslyn were required to present a mechanistic account for their target phenomenon; otherwise, their theories had no explanatory power. Only Kosslyn managed to come up with this account (or at least came close to it): mental visual imagery piggybacks on the infrastructure of vision. The mechanisms underlying gravity remain unknown despite our ability to predict the trajectories of heavenly bodies, satellites and spaceships under the influence of gravitation – our recent success with the Pluto flyby is an example. Yet the predictive power of both theories authorized further research on their grounds. Constraints are facilitative of theory-building to the extent that they eliminate the 'right' set of possible explanations. In the face of growing evidence pointing to the contrary, constraints should be reconsidered and adapted, if not overridden.

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References

Kosslyn, Stephen. *Image and Mind.* 1980.
Kosslyn, Stephen. *Image and Brain.* 1994.
Newton, Isaac, I. Bernard Cohen, and Anne Miller Whitman. *The Principia: Mathematical Principles of Natural Philosophy.* 1999.
Pylyshyn, Zenon. *Cognition and Computation.* 1986.
Smith, George E. *The Emergence of "Newtonian" Physics From the 1760s to the 1800s et seq.* 29 Apr. 2015. Lecture.